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AN ATLAS OF TIROS VII MONTHLY MAPS OF EMITTED RADIATION IN THE 8-12 MICRON ATMOSPHERIC WINDOW OVER THE INDIAN OCEAN AREA

by

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ABSTRACT

The TIROS VII meteorological satellite, launched on June 19, 1963, contained a five-channel medium-resolution scanning radiometer. One of the channels responded to emitted radiation in the 8- to 12-micron portion of the electromagnetic spectrum, where gaseous absorption in the atmosphere is minimal and, therefore, the radiation detected at the satellite originates mainly from the earth's surface and/or clouds. Data from this channel have been compiled and mapped in a series of one 12-day mean map (June 1963) and 18 monthly mean maps (July 1963 through December 1964) of equivalent blackbody temperatures. The maps cover the area enclosed by 45 degrees north latitude, 50 degrees south latitude, 20 degrees east longitude, and 155 degrees east longitude—the area of interest during the International Indian Ocean Expedition (1963-1964).

These satellite observations were originally analyzed in support of the International Indian Ocean Expedition. They are presented here in a separate, compact form for users who are interested primarily in the radiation data and in details concerning the processing, display, analysis, and interpretation of these data.

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INTRODUCTION

During 1963 and 1964, extensive meteorological observations were made in the Indian Ocean area in support of the International Indian Ocean Expedition (IIOE). For part of this time period, namely, from June 19, 1963 through December 1964, the TIROS VII meteorological satellite obtained medium-resolution radiometric measurements in five spectral regions. One of these spectral regions was in the 8- to 12-micron portion of the electromagnetic spectrum, where the radiation detected at the satellite originated mainly from the earth's surface and/or clouds. These radiation data have been summarized in a series of one 12-day mean map (June 19 through 30, 1963) and 18 monthly mean maps (July 1963 through December 1964) of equivalent blackbody temperatures for the area enclosed by 45 degrees north latitude, 50 degrees south latitude, 20 degrees east longitude, and 155 degrees east longitude.

During the IIOE, an elaborate network of ships, land stations, and research and commercial aircraft recorded detailed surface, upper-air, and oceanographic data which can now be correlated with TIROS VII infrared radiation data acquired during this same period. These TIROS VII radiation observations were originally analyzed in support of the IIOE, (Ramage, 1969), but are presented here in a separate, compact form for those users who are interested primarily in a more detailed description of the analysis and interpretation of the infrared data. The interpretation of all data collected during the IIOE can lead to a better understanding of the meteorology and climatology of the Indian Ocean area.

*Air Weather Service member temporarily attached to Goddard Space Flight Center.

THE TIROS VII RADIOMETER EXPERIMENT

The TIROS VII meteorological satellite, launched on June 19, 1963, contained a five-channel medium-resolution scanning radiometer. The optical axis of the radiometer was at a fixed angle of 45 degrees from the spin axis of the satellite. The radiometer viewed in two collinear directions, 180 degrees apart. The spinning motion of the satellite at the rate of about 10 rpm, combined with the orbital motion, with the spin axis approximately fixed with respect to inertial space, produced a rather complicated pattern of scanning. The instantaneous field of view of the radiometer subtended an angle of 5 degrees, which intercepts a spot about 55 km in diameter when viewing the nadir from the TIROS VII mean orbital height of 635 km. The orbital inclination was 58.2 degrees, precluding observations poleward of about 65 degrees latitude.

One of the five channels responded to emitted radiation in the 8- to 12-micron portion of the electromagnetic spectrum, where gaseous absorption in the atmosphere is minimal. Therefore, the radiation detected at the satellite originated mainly from the earth's surface and/or clouds. The energy received by the radiometer was converted into units of equivalent blackbody temperature (in °C). Equivalent blackbody temperature is defined as that temperature of an isothermal blackbody (filling the field of view, as in the laboratory calibration) which causes the same response from the radiometer as does the generally non-Planckian spectral distribution of the radiation emerging from the top of the atmosphere in the direction of the satellite.

A detailed description of the radiometer, the data processing, the scanning modes, the prelaunch calibration, and an observed degradation in the calibration after launch and methods of correcting for this degradation is contained in successive volumes of the "TIROS VII Radiation Data Catalog and Users' Manual," (1964a, 1964b, 1965, and 1966).

INSTRUMENTAL DEGRADATION

The degradation correction factors contained in the "TIROS VII Radiation Data Catalog and Users' Manual," (1964a, 1964b, 1965, and 1966) are given in the form of nomograms. Each measurement was modified to account for instrumental degradation by applying a correction, ΔT_{BB}, to the uncorrected observed temperature, T'_{BB}, in order to obtain the corrected temperature, T_{BB}; that is, $T_{BB} = T'_{BB} + \Delta T_{BB}$. The correction ΔT_{BB} as a function of time was expressed by

$$\Delta T_{BB}(t) \quad = \quad a(t) + b(t)T'_{BB}$$

where $a(t)$ and $b(t)$ are correction factors determined from a linear, least-squares fit of the data given in the degradation nomograms. The degradation with time was sufficiently slow to allow the correction factors to be held constant over periods of from 6 to 9 days during the mapping procedure.

MAPPING PROCEDURE

The data from the 8- to 12-micron channel were compiled into one 12-day map (June 19 through 30, 1963) (Figure 1) and 18 monthly maps (July 1963 through December 1964) (Figures 2-19) of mean equivalent blackbody temperatures. The equivalent blackbody temperature measurements were averaged by an IBM 7094 computer over a field of equally spaced grid points, superimposed on a 1:40-million scale Mercator projection map base with a resolution of 5 degrees of longitude per mesh interval. Because of the nature of a Mercator projection, the spacing of the grid points is variable in latitude, ranging from 5 degrees of latitude at the equator to about 2.5 degrees of latitude per mesh interval at latitude 60 degrees. A simple filter having three weights in both the meridional and zonal directions was passed over the grid array to smooth out perturbations due to spatial and temporal sampling biasing in the data, resulting from the interrogation pattern and history of the satellite. The weighting array of the 3 × 3 filter was the following:

.0625	.1250	.0625
.1250	.2500	.1250
.0625	.1250	.0625

The weighted temperature was assigned to the central value. The computer was instructed to reject all data with scan nadir angles greater than 40 degrees, to lessen limb-darkening effects. Also, to avoid mislocation of data, a provision was added that whenever the minimum nadir angle occurring within a scan was greater than 38 degrees, all data from the entire scan were rejected. All ambiguous portions of what is known as the "alternating open mode," as well as most of the "closed mode," were eliminated, thus leaving essentially only the "single open mode," in which one can have fairly high confidence in accurate location of the data ("TIROS VII Radiation Data Catalog and Users' Manual," 1964a; Bandeen, 1962).

ANALYSIS PROCEDURE

Isotherms were drawn by hand over the computer-produced grid-print maps with a contour interval of 5°C. Dashed isotherms indicate areas where the number of individual measurements falling within the square of influence of a grid point was less than 100. Isotherms were not drawn where there were no measurements, and these regions are indicated by the annotation "NO DATA." In regions of a tight gradient, the coldest central T_{BB} value was plotted and some intermediate 5° isotherms were omitted.

Table 1 lists the approximate number of orbits per month which passed through the Indian Ocean area. The charts which contain 105 orbits or less tend to present more detailed thermal gradients than those with larger orbital coverage and thus greater numerical averaging.

The regions having equivalent blackbody temperatures of 0°C or less are shaded to indicate cloud effective radiation heights at the approximate height of the freezing level or higher. Effective radiation height is that height in the atmosphere where the ambient air temperature equals the equivalent blackbody temperature.

Table 1

Approximate Number of Orbits Per Month Which Passed Through the Indian Ocean Area.

1963		1964	
Month	Number of Orbits	Month	Number of Orbits
June	60	January	150
July	160	February	140
August	150	March	155
September	145	April	135
October	170	May	100
November	130	June	60
December	105	July	60
		August	70
		September	45
		October	70
		November	110
		December	60

INTERPRETATION OF THE MAPS

The user of these maps must be aware of certain atmospheric effects in interpreting the satellite measurements. In particular, thin cirrus clouds act as if they were partially transparent, permitting the warmer radiation from below to be recorded by the TIROS radiometer. Also, if scattered to broken cloud decks of varying transparency are viewed, the radiation originating from the ground and the various cloud layers contribute to the integrated intensity detected by the satellite. Under these two conditions, the cloud effective radiation heights tend to fall below the top level of the cloud layers. However, when a homogeneous overcast cloud layer or clear skies over a sea or land region fill the field of view of the radiometer, a uniform interpretation of the equivalent blackbody temperatures, in terms of surface or cloud-top temperatures, can be made. Even in the 8- to 12-micron window, losses due to the absorption of infrared energy, mainly by water vapor and ozone, can cause the isotherms to be colder than they would be in the absence of an atmosphere. For example, in the case where there are middle and high clouds in the radiometer field of view, the water vapor and ozone above the clouds can cause the isotherms to be 3 to 5 degrees colder than they would be without an atmosphere. The worst case, a very moist atmosphere with clear skies, can produce a 10-degree difference (Wark, et al., 1962). The cumulative results of these factors could cause an error of plus-or-minus several thousand feet in cloud top height estimation. The monthly maps of equivalent blackbody temperatures include data from daytime and nighttime orbits; hence the averaging process tends to smooth out the diurnal variations of surface temperatures and cloud heights.

The analysis and interpretation of satellite radiation data have been discussed extensively in the literature. For further information concerning analyses of the type shown here, the interested reader may consult (for example) papers by Allison and Warnecke (1966, 1967), Allison, Kreins, Godshall, and Warnecke (1969), and Winston (1966).

ACKNOWLEDGMENTS

This project was conducted under the guidance and supervision of Mr. William R. Bandeen, Head of the Planetary Radiations Branch, Goddard Space Flight Center. The computer processing of the vast amount of data was facilitated by Mr. Robert T. Hite, Head of the Mathematics and Computing Group of the Planetary Radiations Branch.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, October 30, 1968
160-44-03-96-51

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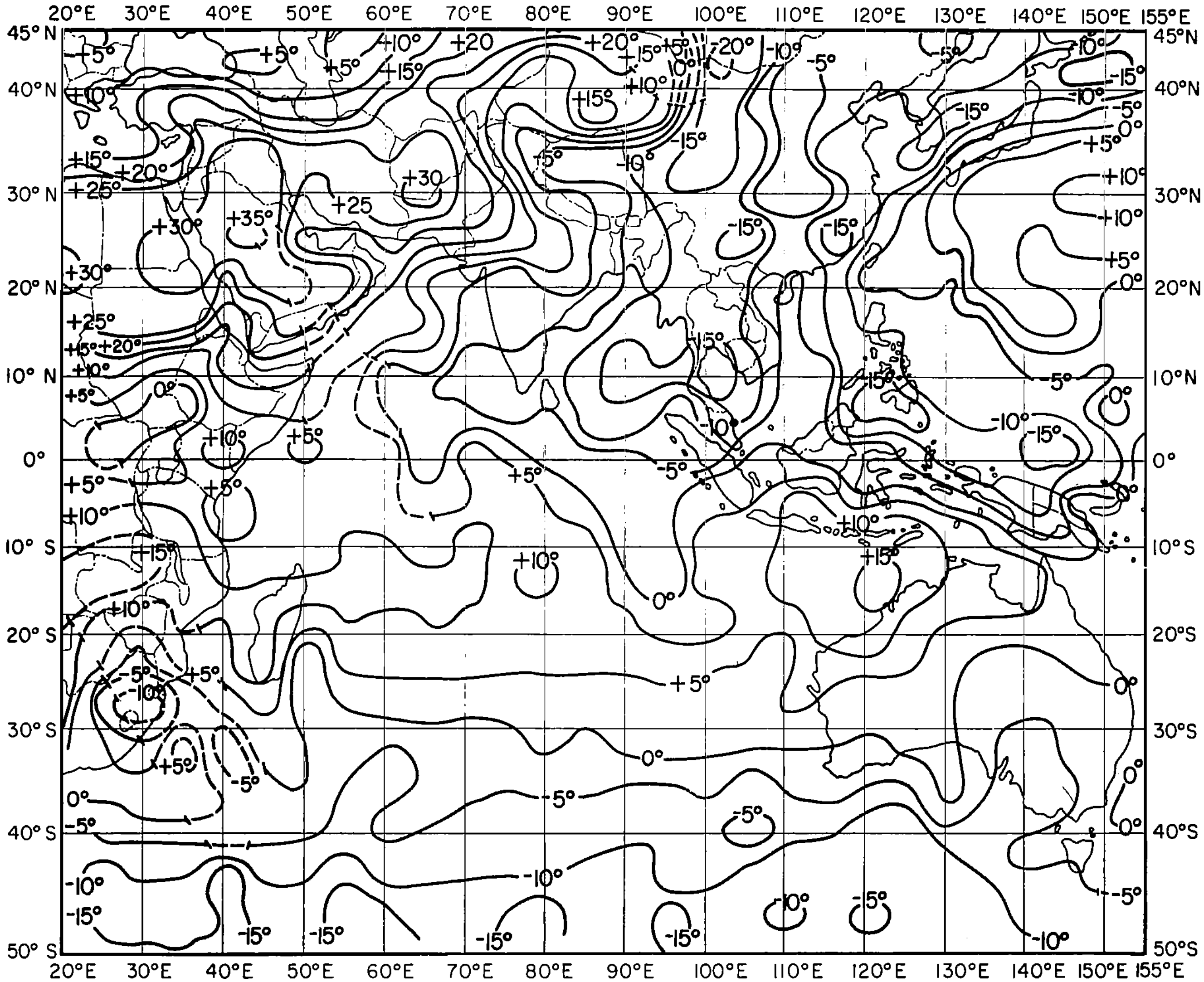

Figure 1—June 1963, 12-day average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

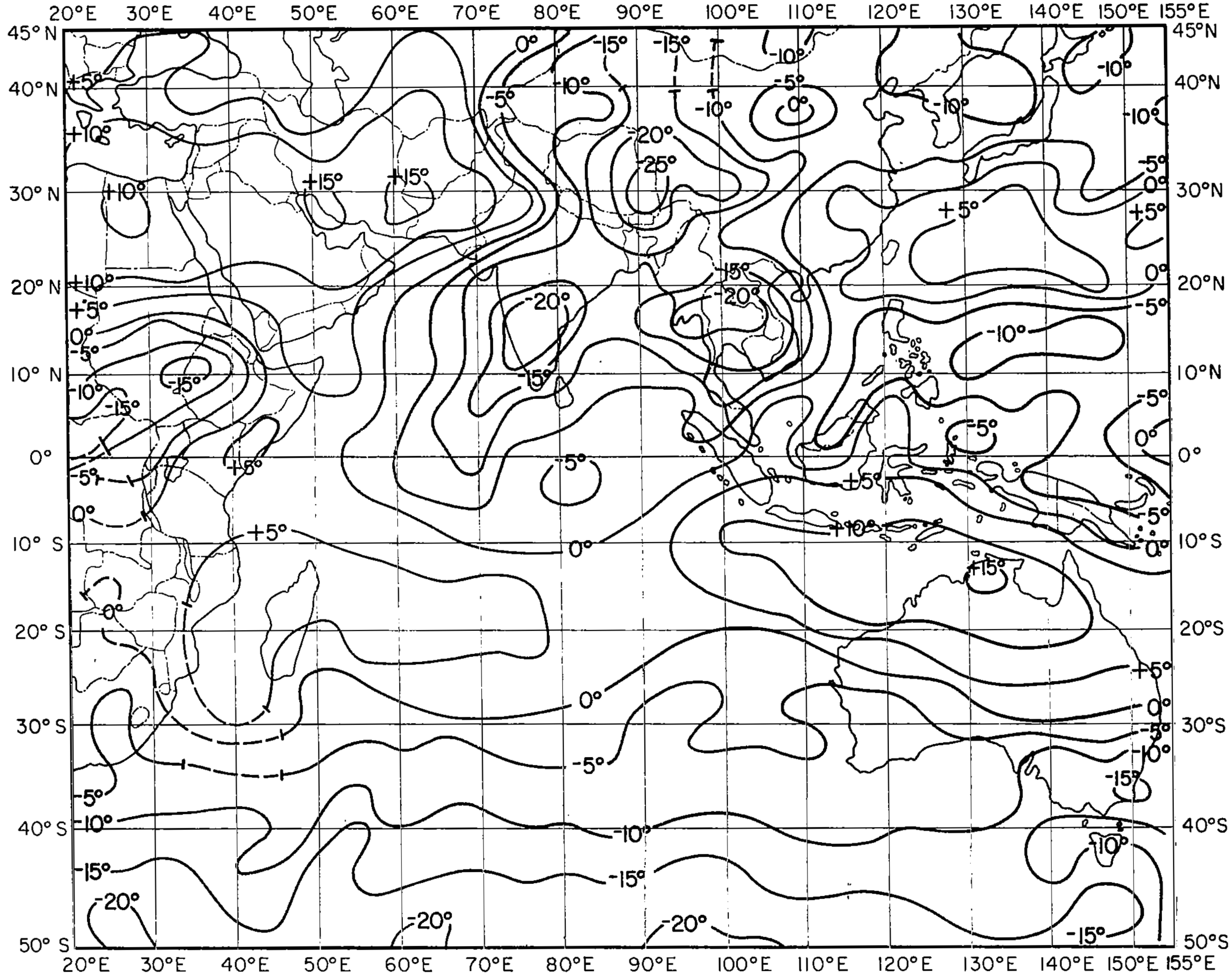

Figure 2—July 1963, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

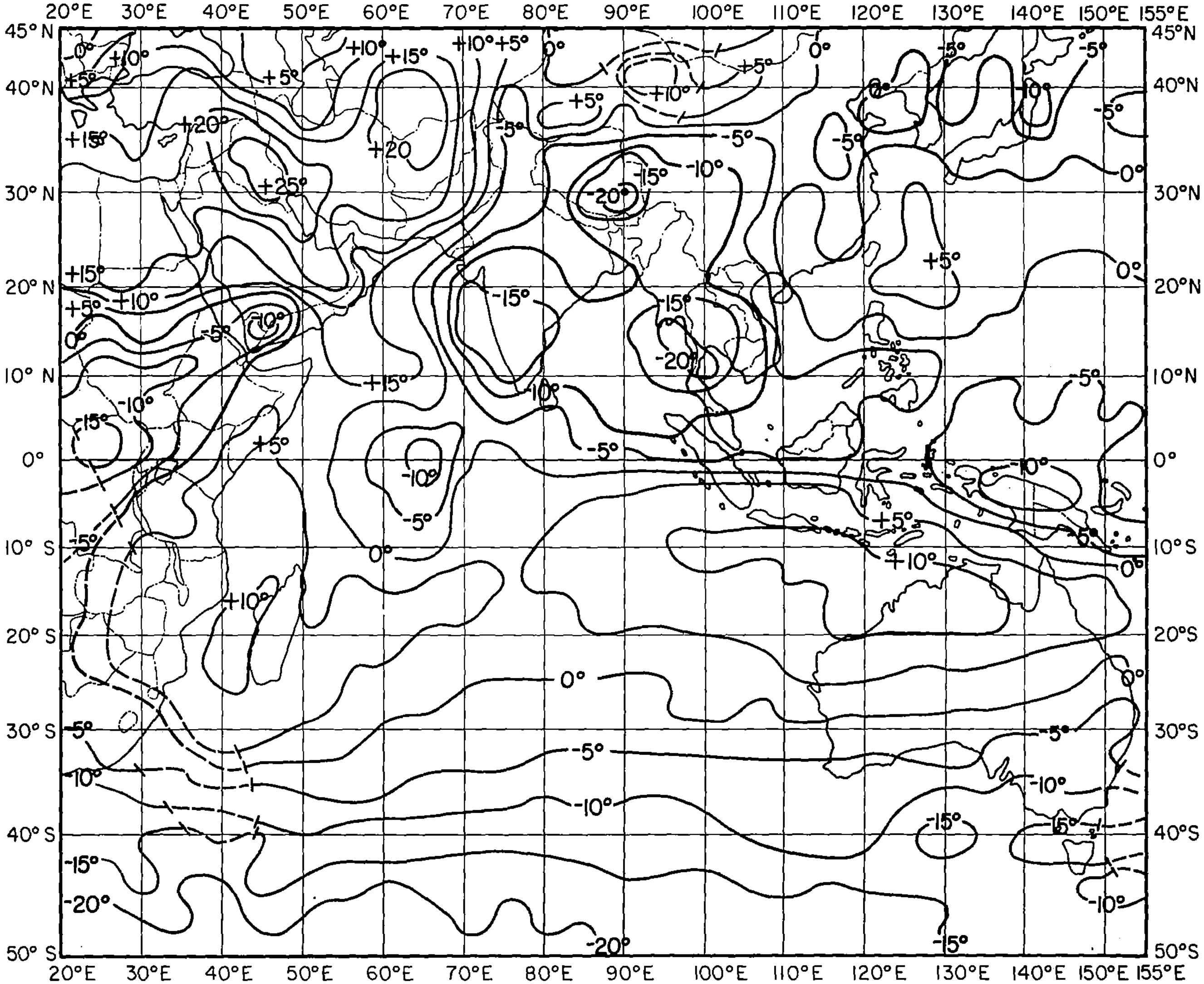

Figure 3—August 1963, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

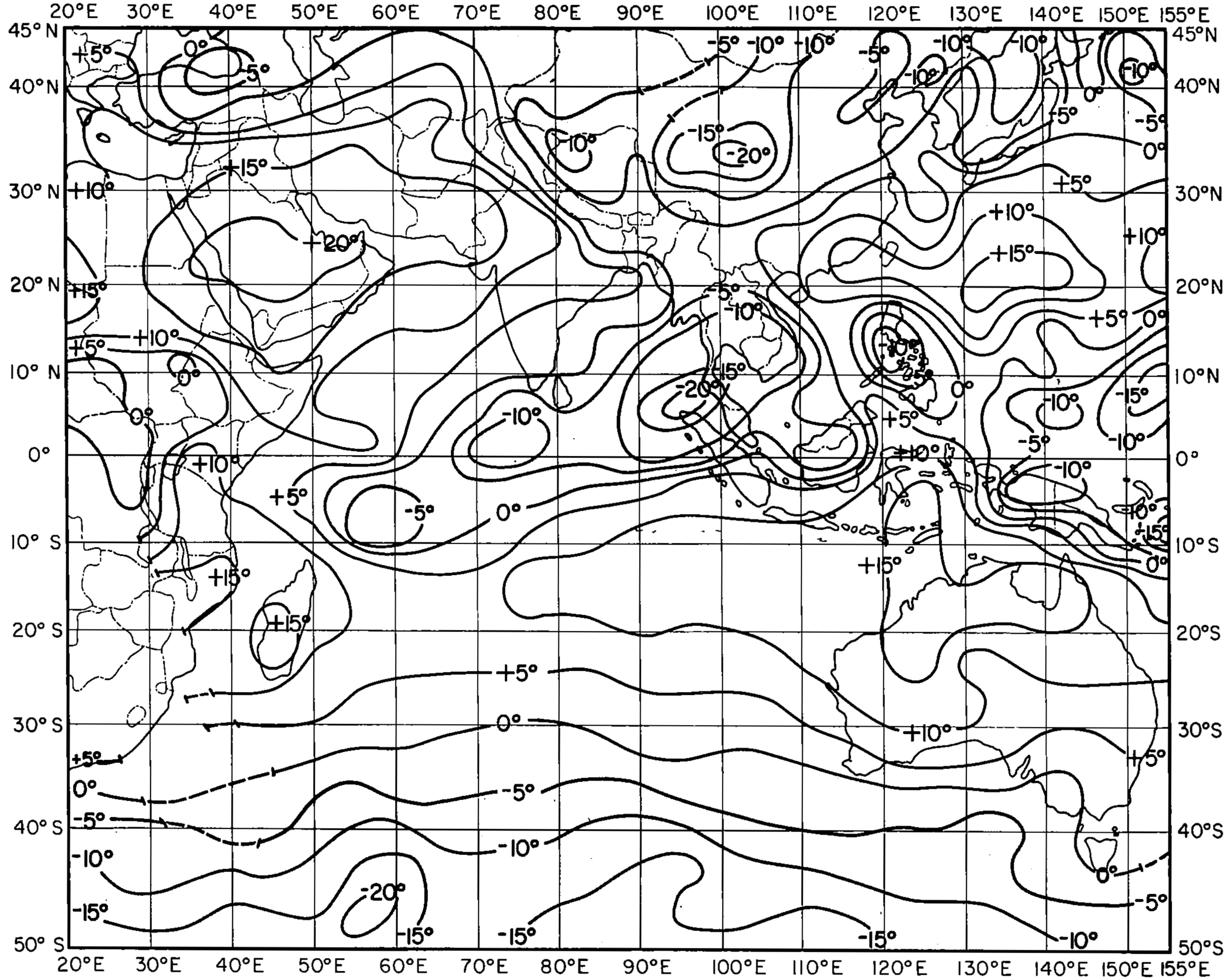

Figure 4—September 1963, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

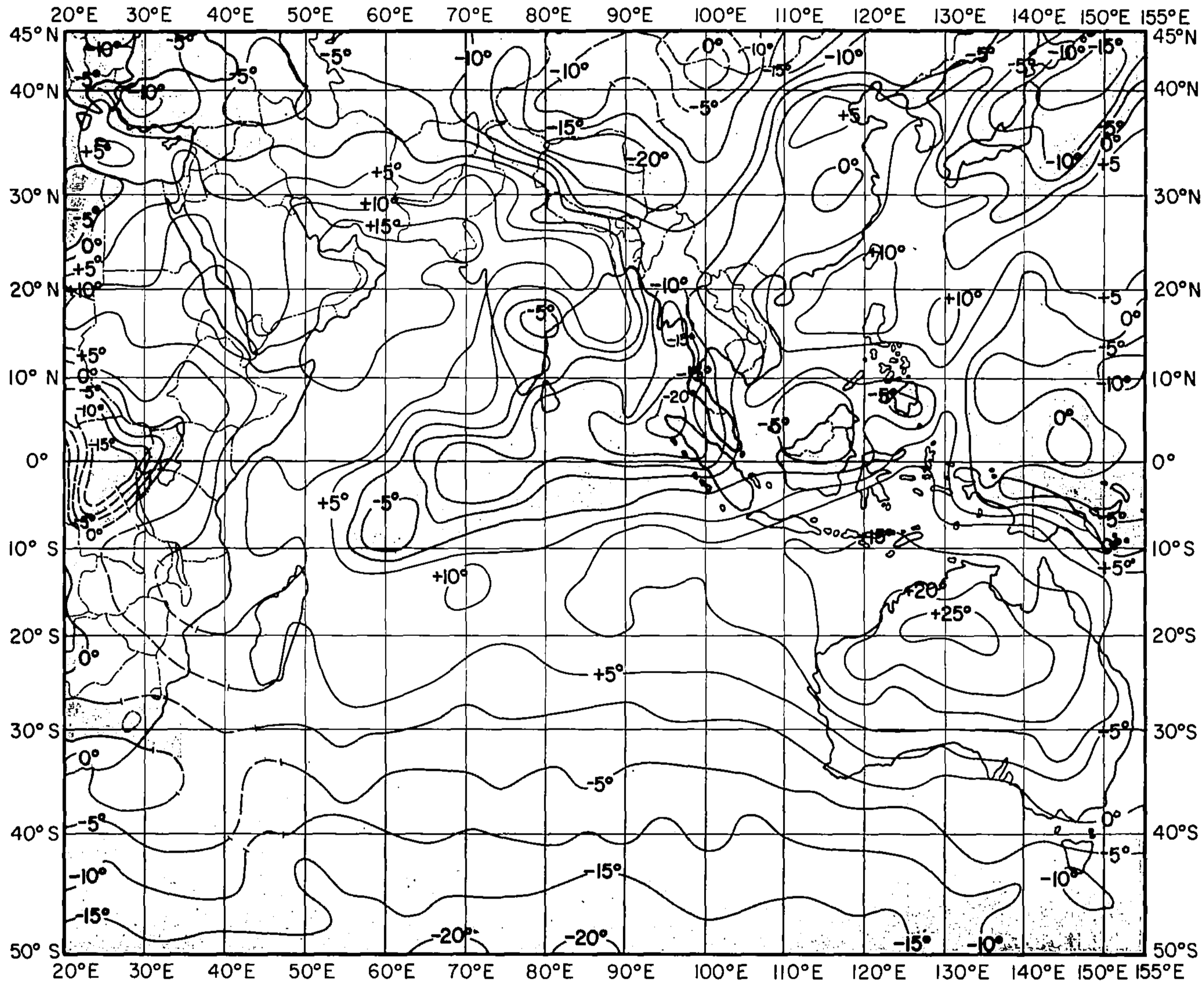

Figure 5—October 1963, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

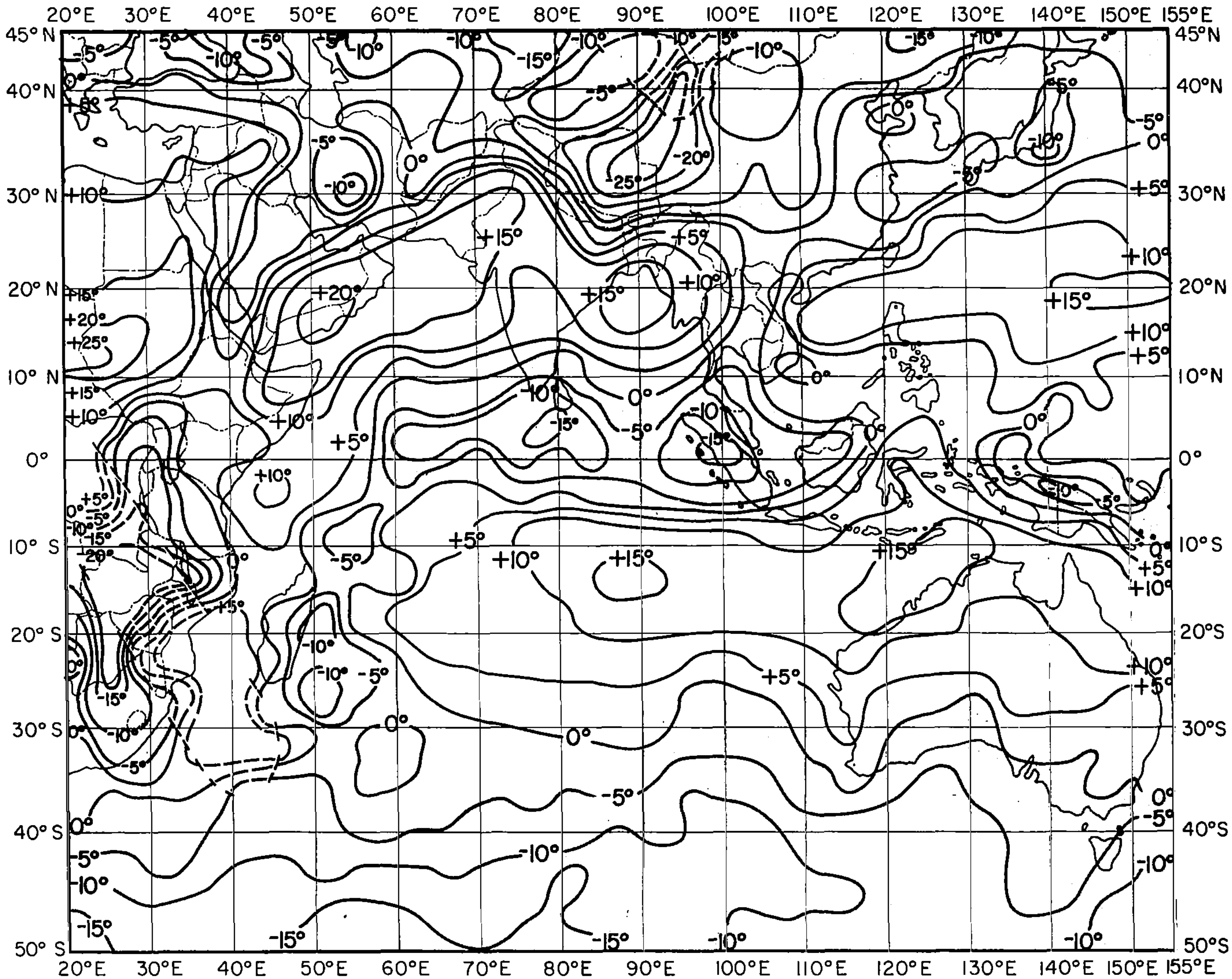

Figure 6—November 1963, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8–12μ, corrected for degradation.

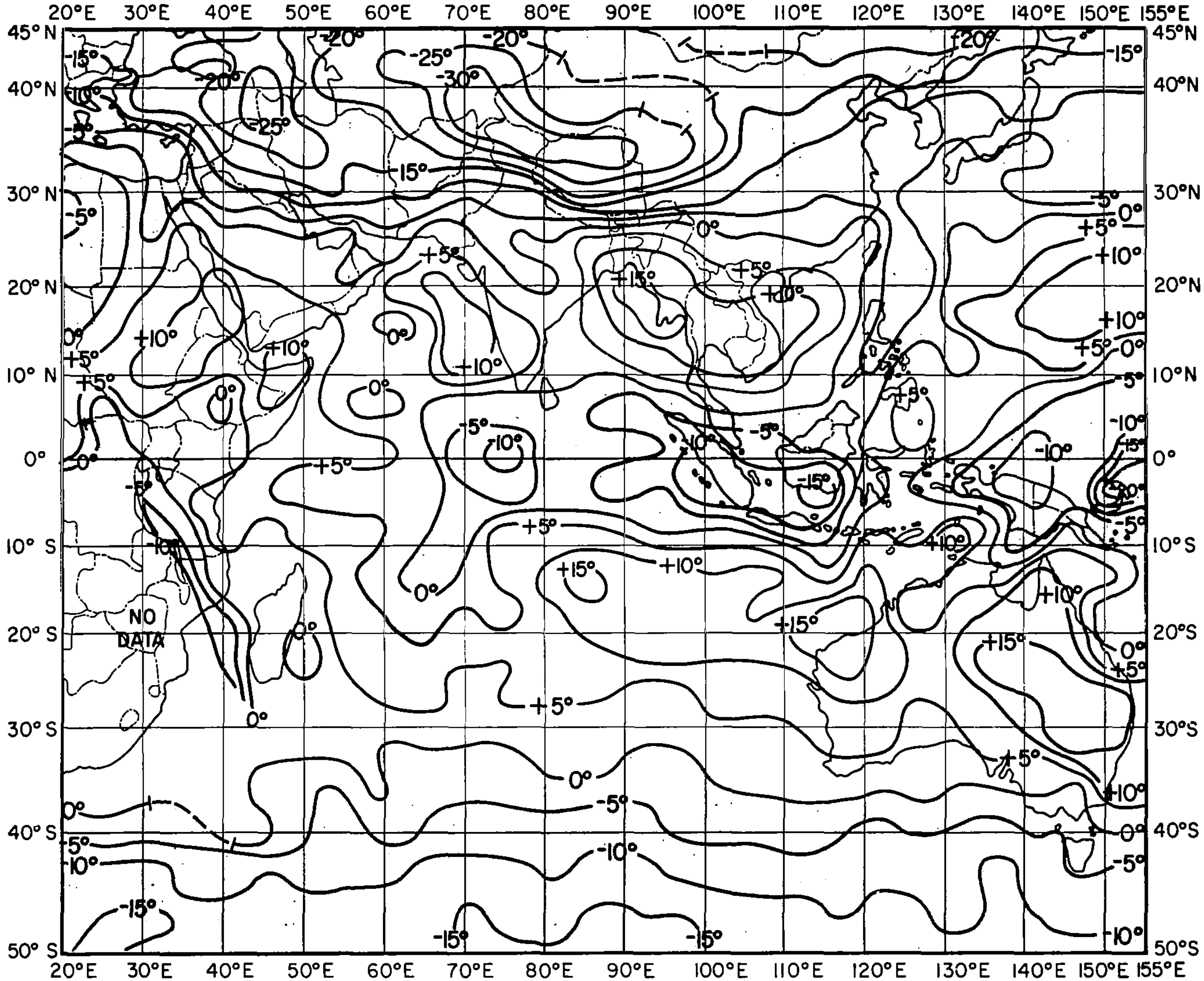

Figure 7—December 1963, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

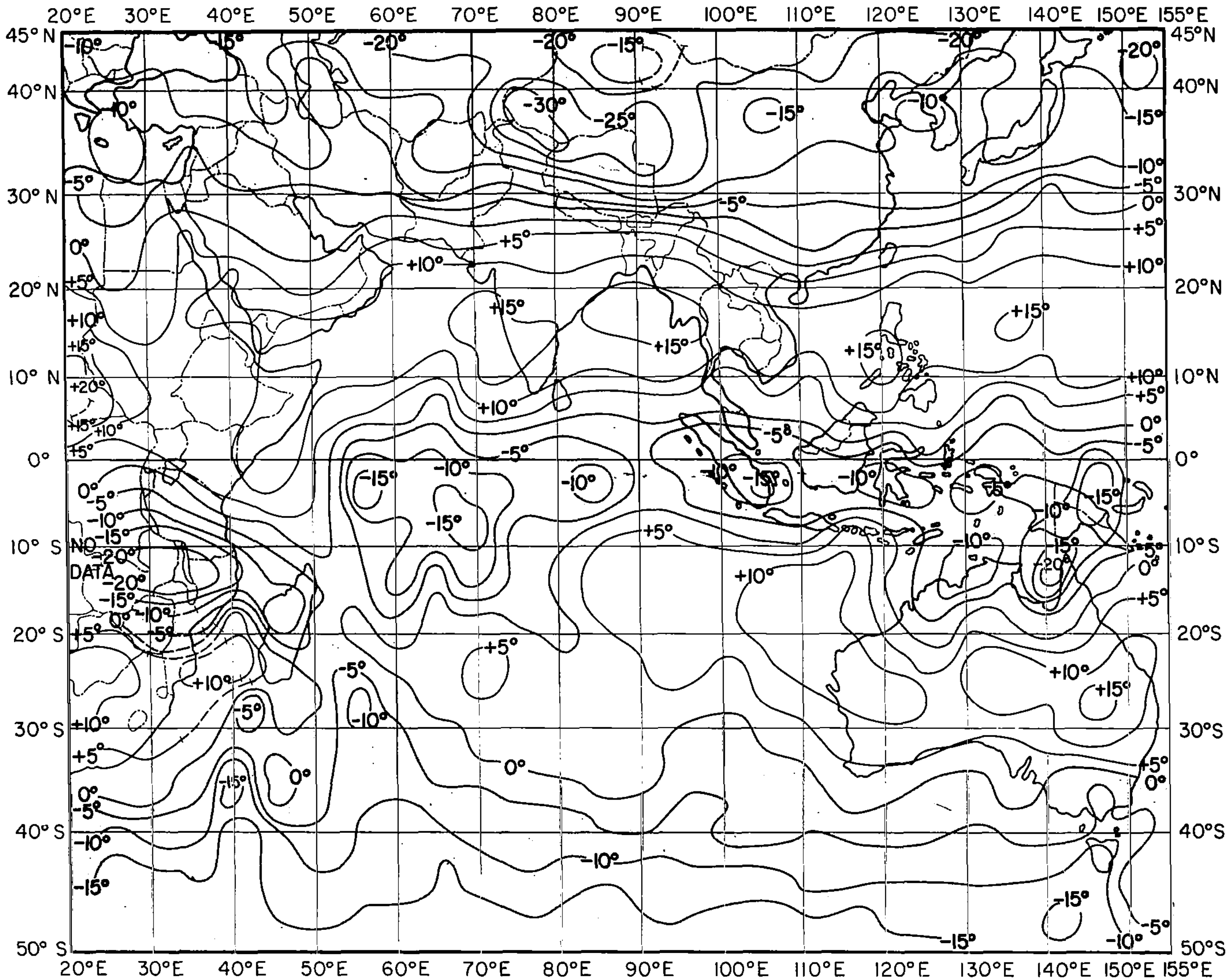

Figure 8—January 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

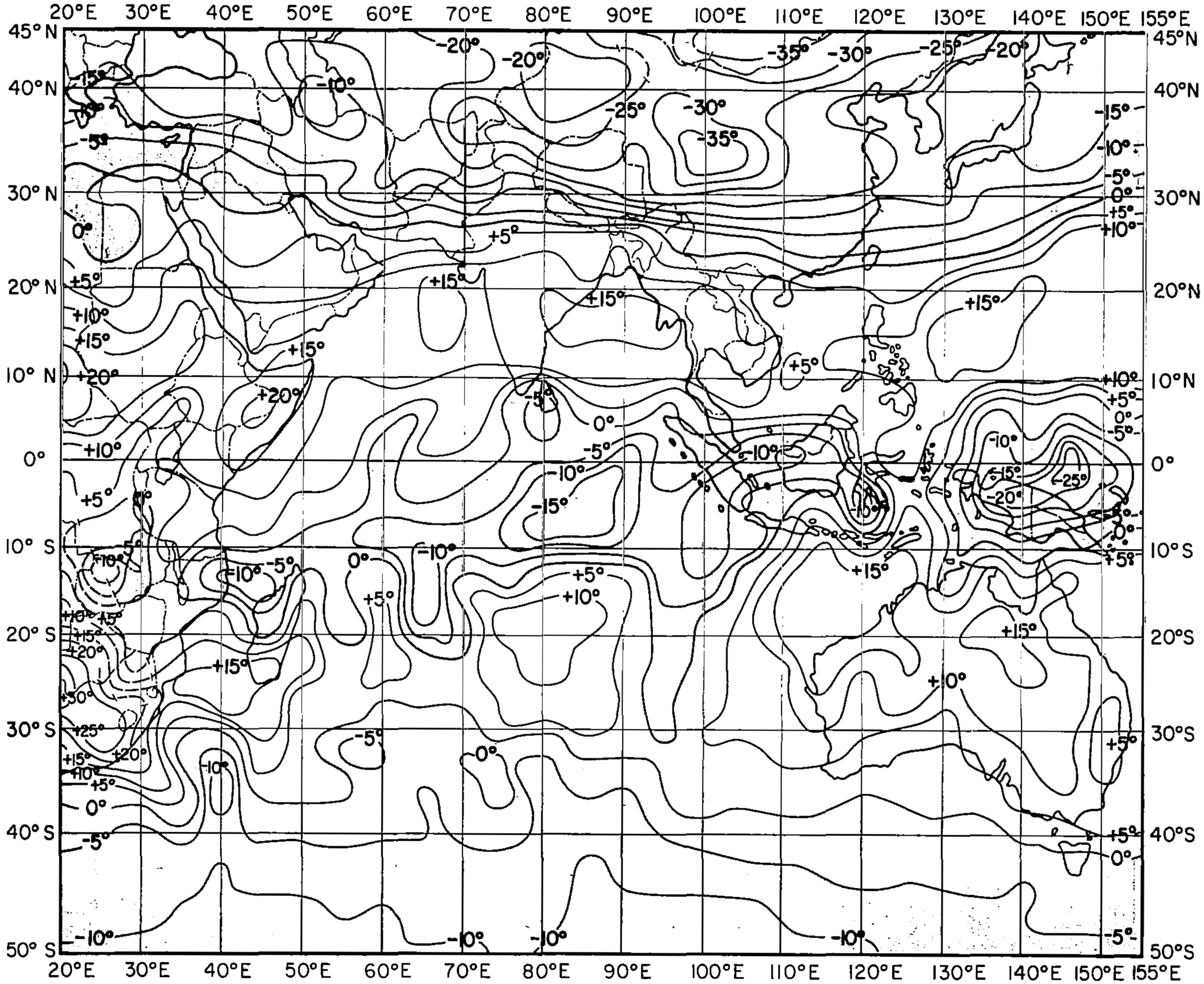

Figure 9—February 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

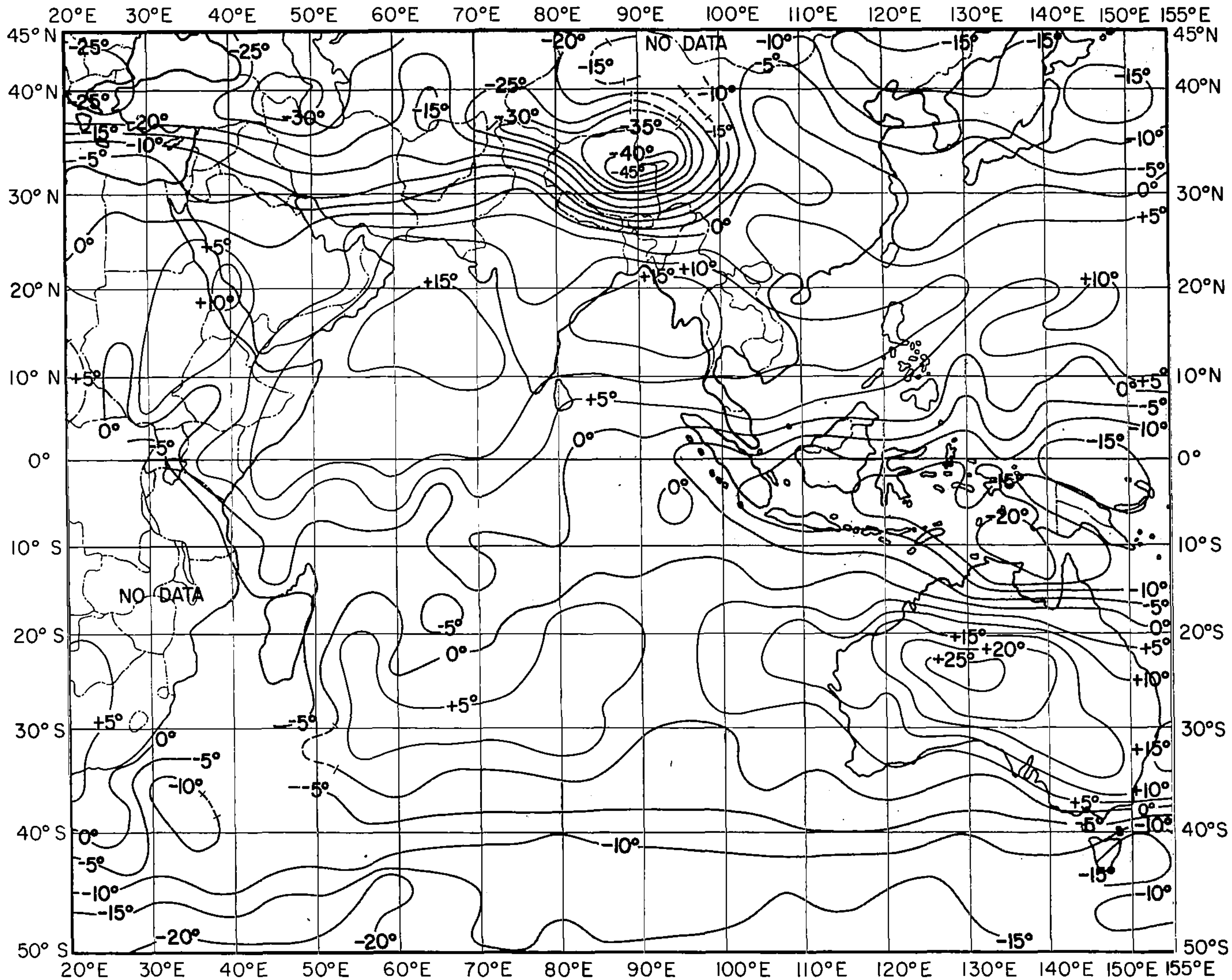

Figure 10—March 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8–12μ, corrected for degradation.

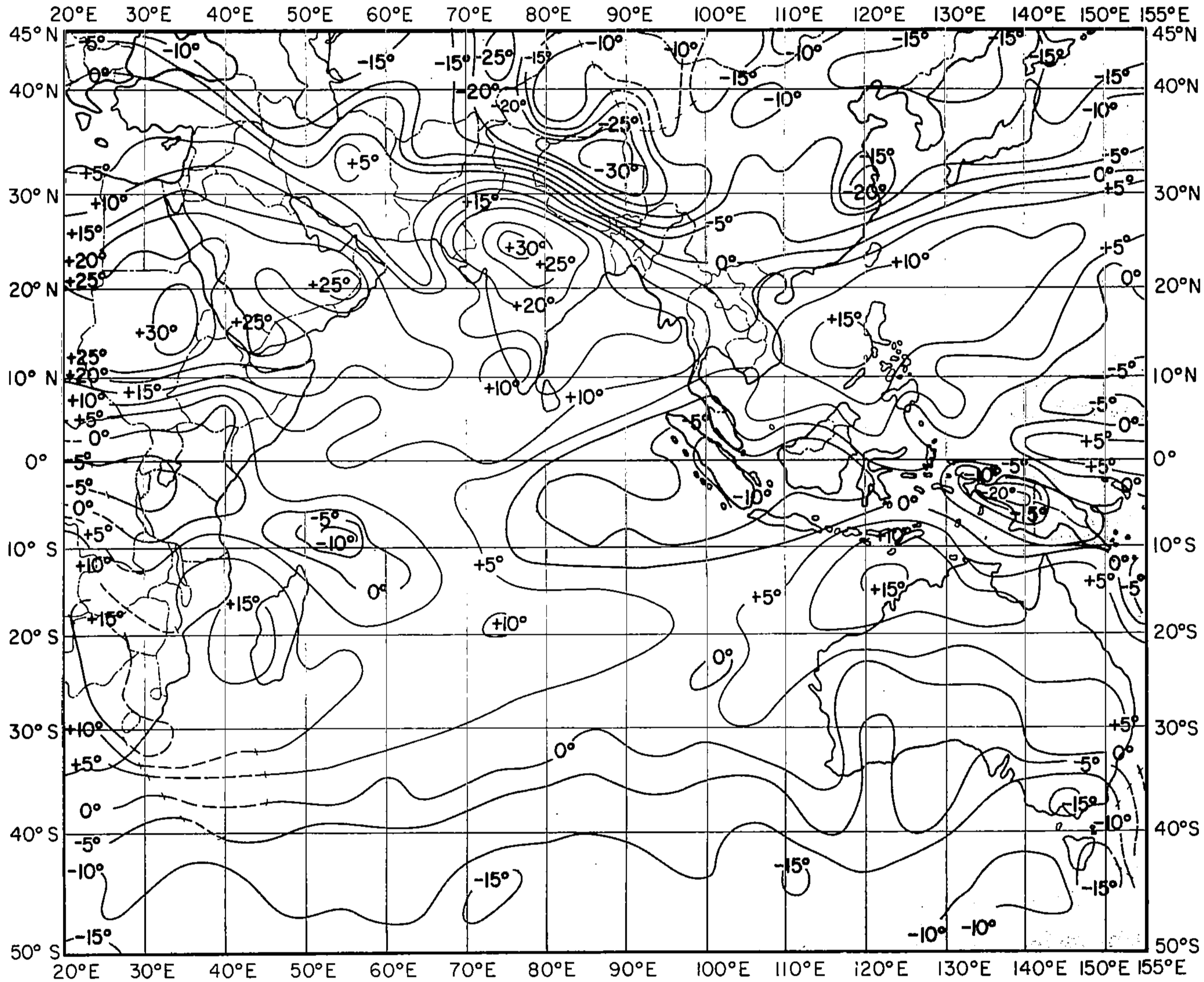

Figure 11—April 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

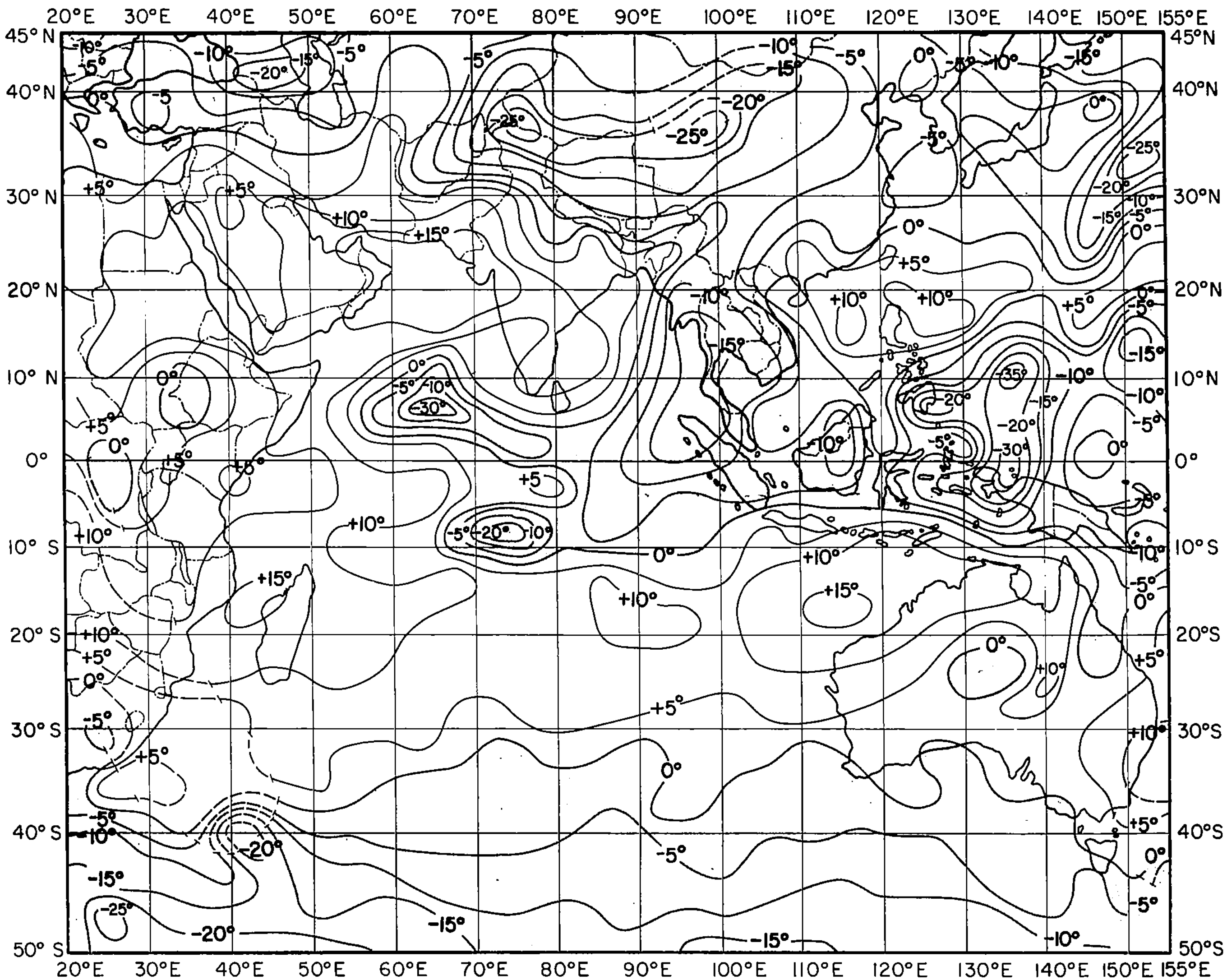

Figure 12—May 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8-12μ, corrected for degradation.

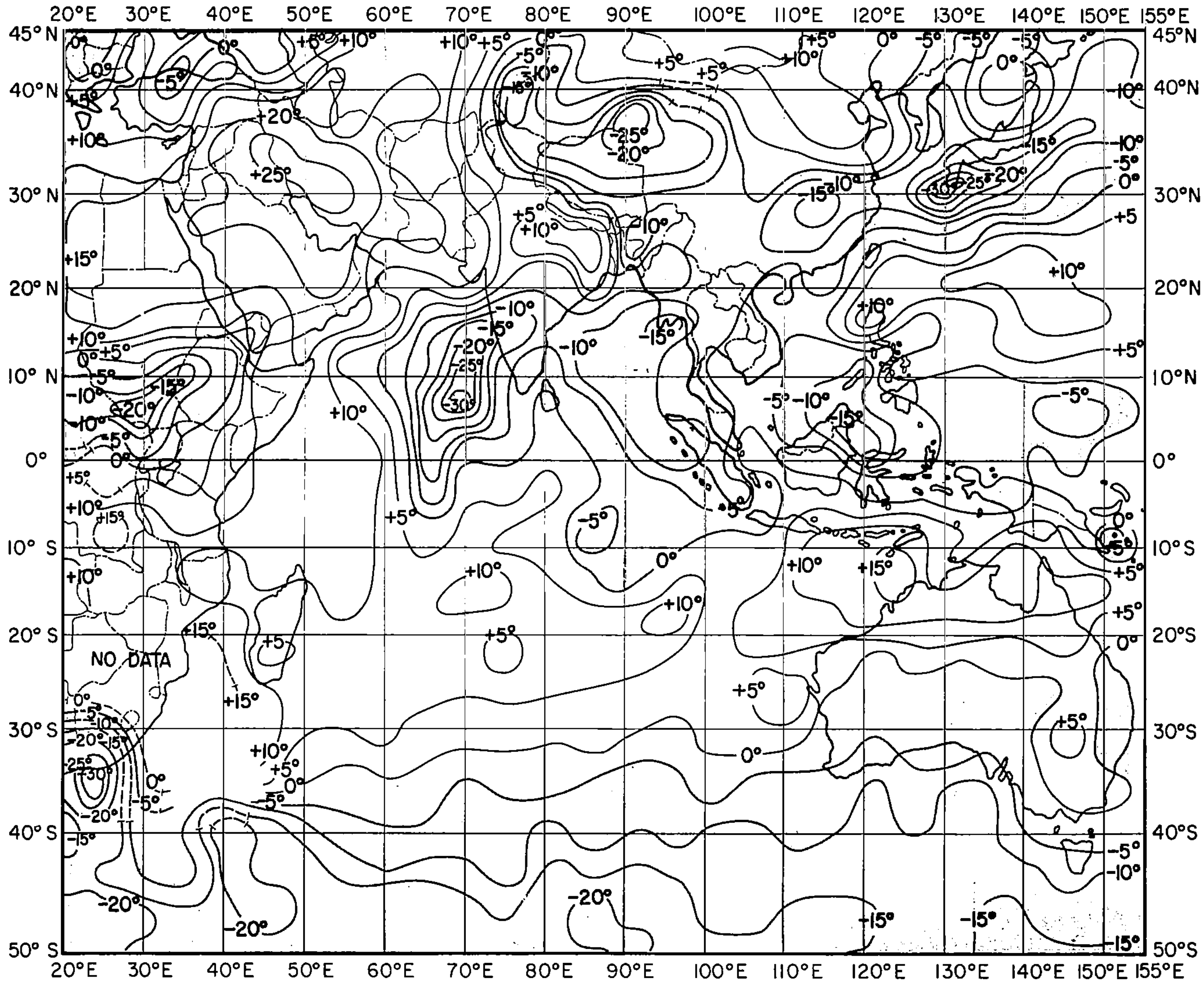

Figure 13—June 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8–12μ, corrected for degradation.

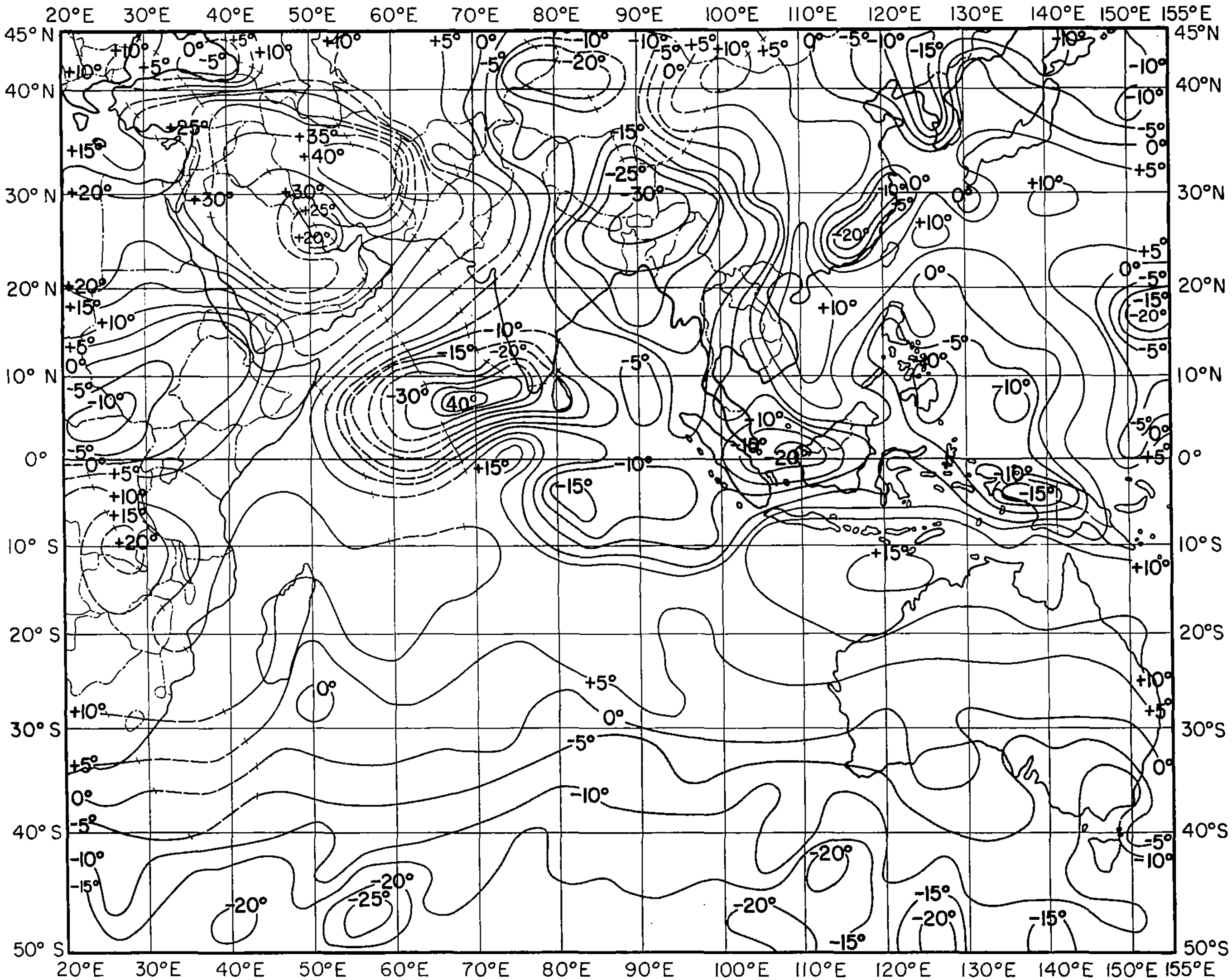

Figure 14–July 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8–12μ, corrected for degradation.

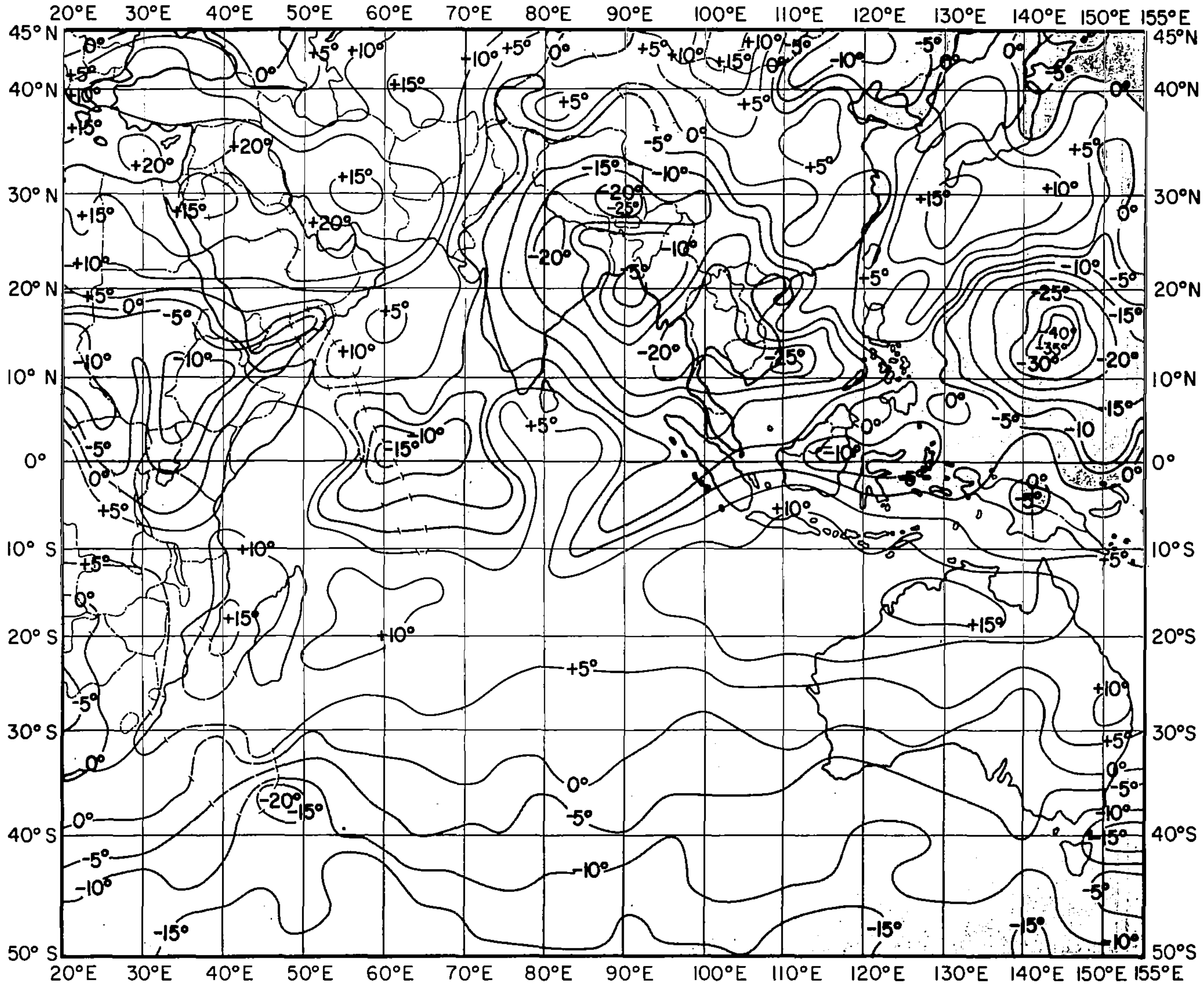

Figure 15—August 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

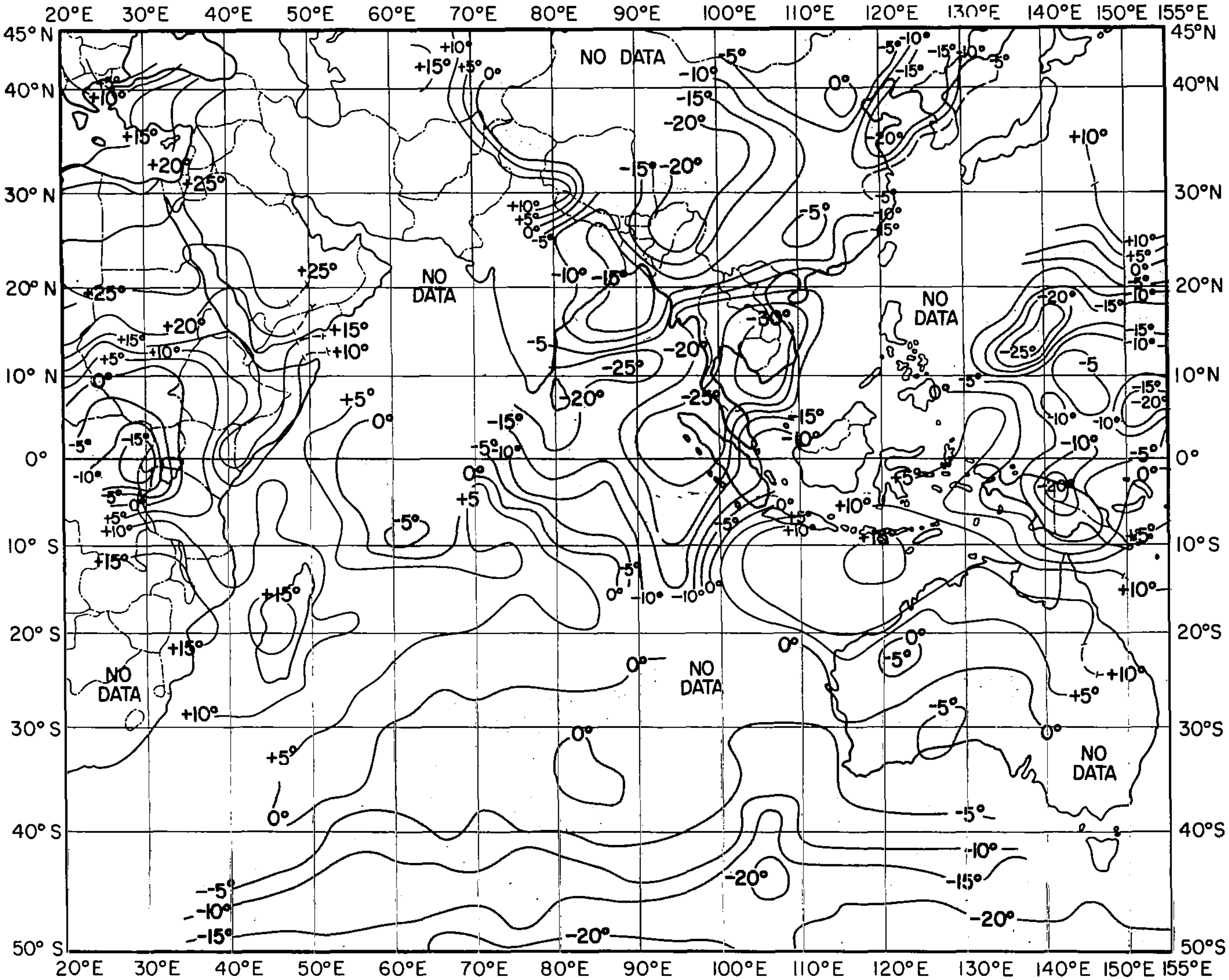

Figure 16–September 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

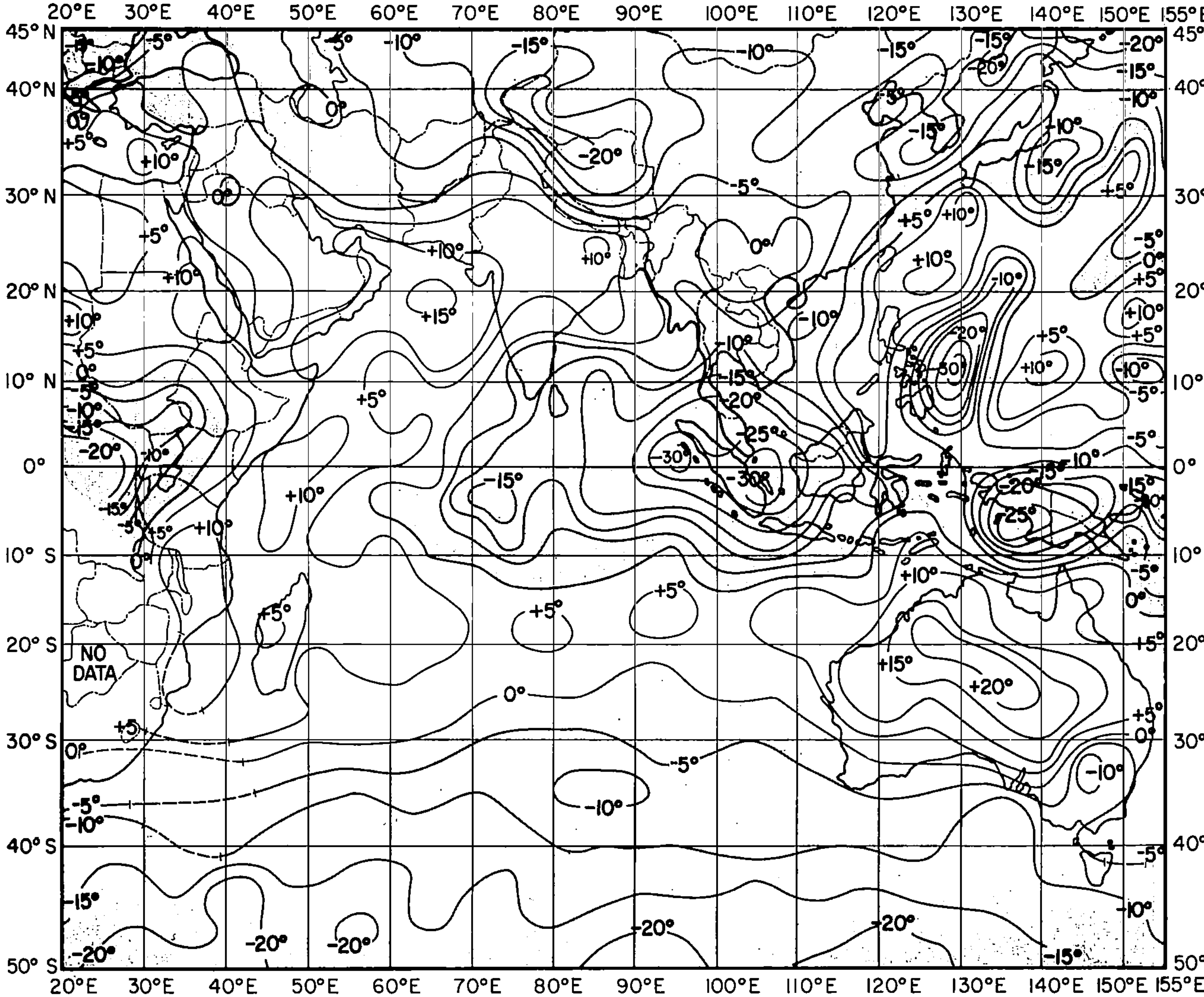

Figure 17—October 1964, monthly average of equivalent blackbody temperature (°C)
TIROS VII, 8–12μ, corrected for degradation.

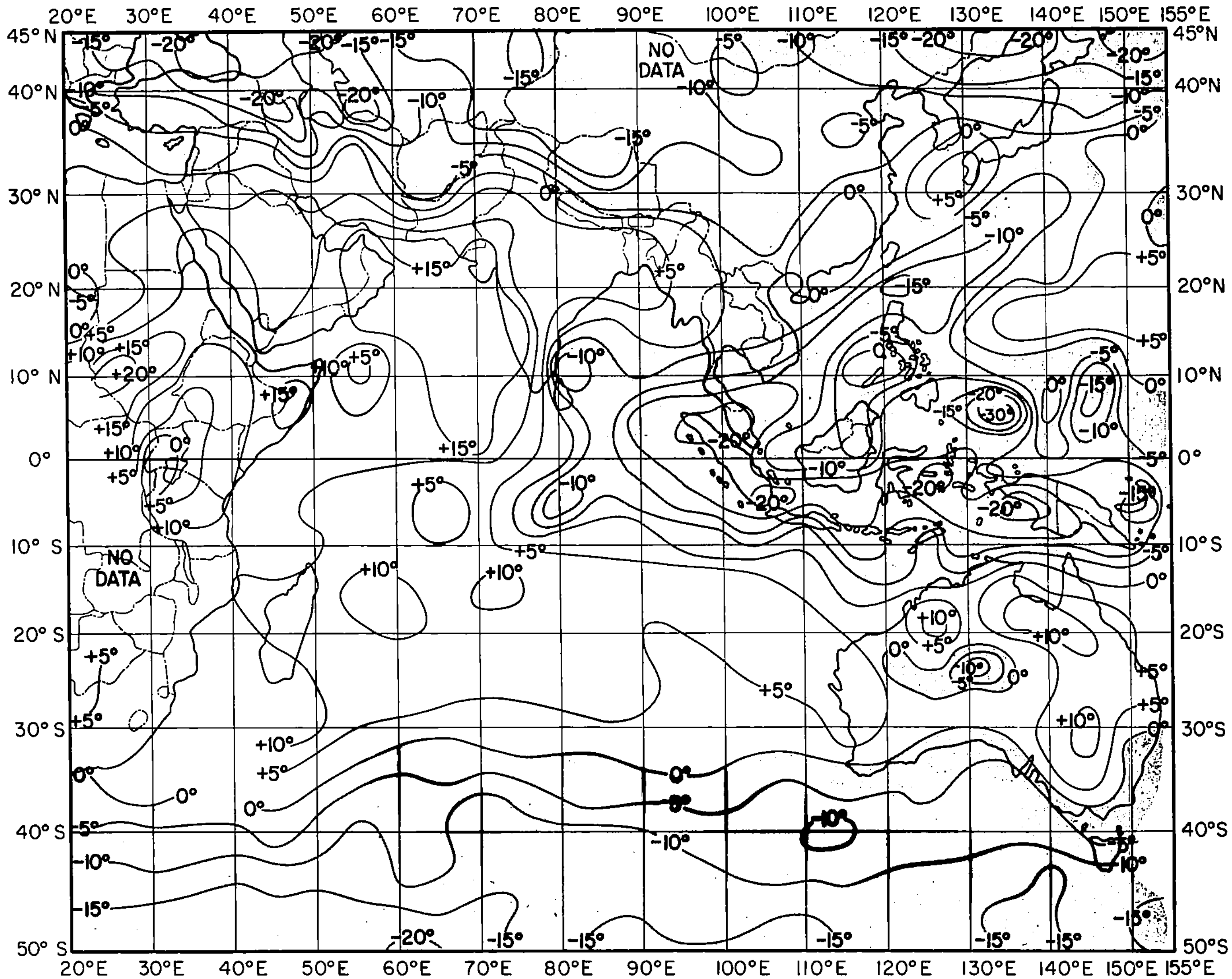

Figure 18—November 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

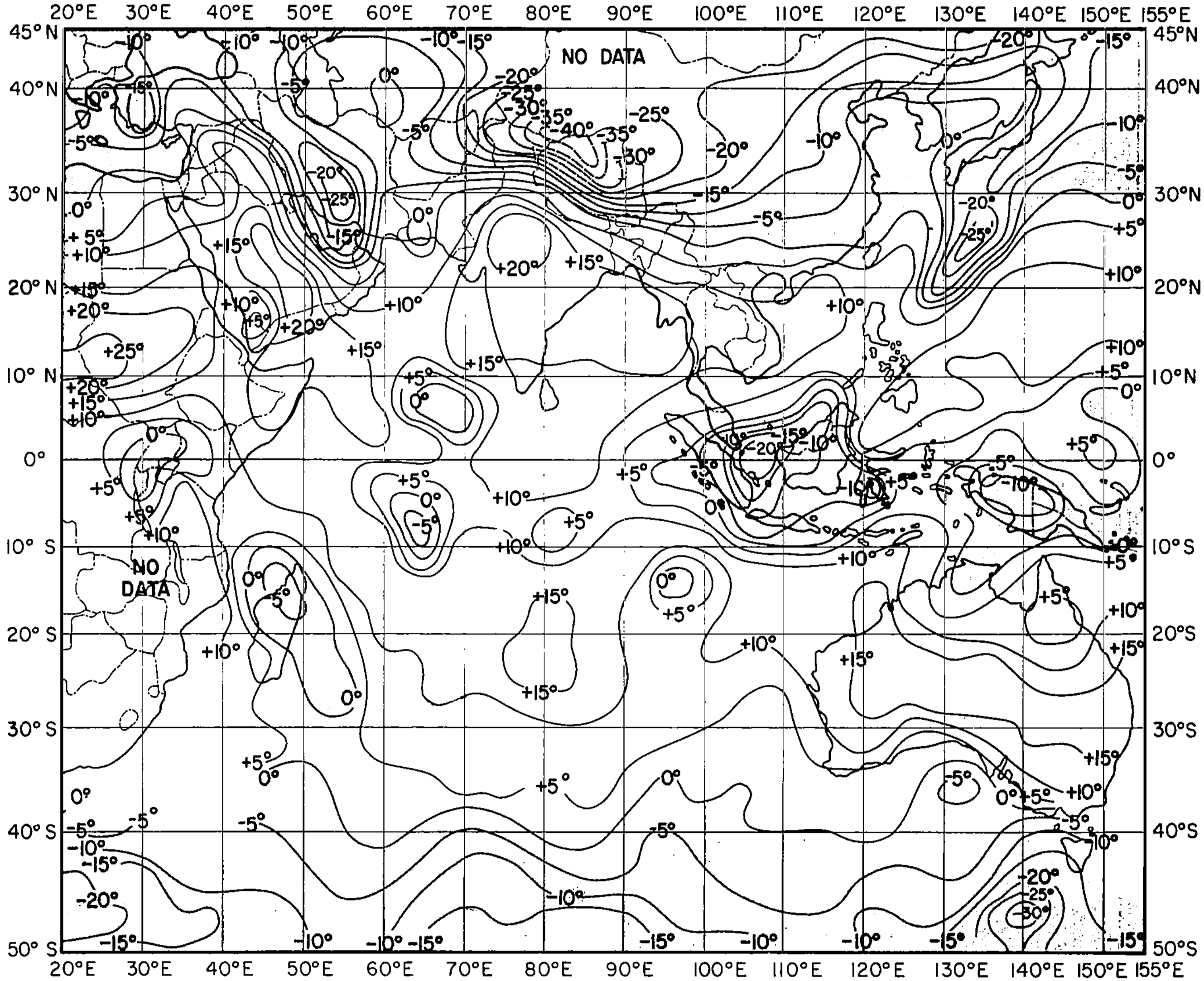

Figure 19—December 1964, monthly average of equivalent blackbody temperature (°C) TIROS VII, 8-12μ, corrected for degradation.

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